RADIONUCLIDIC IMPURITIES IN PERTECHNETATE SOLUTION ELUTED FROM ^{99m}Tc-CHROMATOGRAPHIC GENERATOR LOADED WITH ^{99}Mo-FISSION PRODUCT

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ABSTRACT

Medical radioisotope of ^{99m}Tc was firstly produced in Indonesia through the nuclear reaction of ^{98}Mo (n,γ) ^{99}Mo → ^{99m}Tc. The separation of the resulting ^{99m}Tc from the post-irradiated natural MoO_3 was carried out by solvent extraction using methyl ethyl ketone. Instead of this method, Radioisotope Production Center (RPC) BATAN has routinely produced ^{99m}Tc-chromatographic generator loaded with ^{235}U-fission-produced ^{99}Mo to provide ^{99m}Tc. By such generator, ^{99m}Tc can be easily and repeatedly liberated in the form of pertechnetate by vacuum elution using saline solution. Some fission-produced radionuclides, however, potentially contaminate the pertechnetate fraction. Gamma spectrometric determination was carried out to evaluate the level of radionuclidic impurities contaminating ^{99m}Tc-pertechnetate solution eluted from ^{99m}Tc-chromatographic generator produced over a 10-month period in 1993 – 1994. Radioactivity yield of the resulting ^{99m}Tc was independent to the origin of the loaded ^{99}Mo. The ^{99m}Tc-pertechnetatate fractions were frequently contaminated with ^{99}Mo, ^{131}I and ^{103}Ru, but the contamination did not exceed maximum permissible level. The fluctuation of contamination level may be influenced by irradiation parameters and separation techniques applied to the production of the loaded ^{99}Mo.

INTISARI

Radioisotop medik ^{99m}Tc pertama kali dibuat di Indonesia melalui reaksi inti ^{98}Mo (n,γ) ^{99}Mo → ^{99m}Tc . Pemisahan spesi ^{99m}Tc dari bahan sasaran MoO_3 alam pasca iradiasi dilakukan dengan ekstraksi menggunakan metil etil keton. Dewasa ini Pusat Produksi Radioisotop (PPR) BATAN telah secara rutin memproduksi generator kromatografi ^{99m}Tc yang diisi dengan radioisotop ^{99}Mo produk fissi ^{235}U untuk penyediaan radioisotop ^{99m}Tc. Dari generator ^{99m}Tc tersebut, spesi ^{99m}Tc dapat dengan mudah dan berulang dihasilkan dalam bentuk perteknetat melalui elusi vakum menggunakan larutan salin. Akan tetapi fraksi perteknetat yang dihasilkan sangat mungkin terkontaminasi oleh radionuklida hasil fissi yang lain. Evaluasi melalui metoda spektrometri gamma telah dilakukan terhadap fraksi perteknetat dari generator ^{99m}Tc yang diproduksi dalam kurun waktu Juli 1993 sampai Mei 1994. "Yield" keradioaktifan spesi ^{99m}Tc terbukti tidak tergantung pada jenis dan asal dari radionuklida ^{99}Mo hasil fissi yang digunakan, tetapi fraksi perteknetat yang diperoleh selalu terkontaminasi oleh ^{99}Mo, ^{131}I dan ^{103}Ru. Fluktuasi kontaminasi radionuklida tersebut dipengaruhi oleh parameter iradiasi dan teknik pemisahan dalam proses produksi ^{99}Mo, tetapi tingkat kontaminasi tidak melebihi batas maksimal yang disyaratkan.

INTRODUCTION

Technetium-99m (^{99m}Tc) is the most important radioisotope used in nuclear medicine field [1,2]. It was firstly produced in Indonesia through the nuclear reaction of ^{98}Mo (n,γ) ^{99}Mo → ^{99m}Tc, in the Bandung Reactor Center (presently named The Research Center for Nuclear Technique) of National Atomic Energy Agency (BATAN) [3] using natural molybdenum in the form of MoO_3 as target material. The resulting ^{99m}Tc was separated from post-irradiated target by solvent extraction using methyl ethyl ketone [4].

At present, ^{99m}Tc-generator system is commercially available. With the generator system, the separation of ^{99m}Tc can be carried out repeatedly and easily in hospital. Based on the using separation techniques, there are 3 types of ^{99m}Tc-generator system [5], i.e. extraction, sublimation and chromatography. The chromatographic generator is simpler than the two others and, therefore, it becomes to be the most popular system for providing ^{99m}Tc. The Radioisotope Production Center (RPC) BATAN has routinely produced chromatographic generators loaded with fission produced ^{99}Mo [6]. The ^{99m}Tc fraction is easily separated by vacuum elution using sterile saline solution.

By using fission-produced ^{99}Mo, the generator system producing ^{99m}Tc is potentially contaminated by other radionuclides produced by fission because some fission products are difficult to eliminate completely [7]. We have been concerned by the consistent appearance of ^{99}Mo, ^{131}I and ^{103}Ru in the ^{99m}Tc fraction eluted from ^{99m}Tc-generator produced by RPC. These contaminants must be determined and may not exceed a certain maximum permissible level [8].

In order to evaluate the level of radionuclidic impurities and the characteristic of the ^{99m}Tc-generator manufactured by RPC, the pertechnetate solution eluted from the

generator system has been subjected to gamma spectrometric analysis. In this paper we report the evaluation of ^{99m}Tc-generators produced over a period of July 1993 to May 1994.

MATERIALS AND METHODS

The ^{99m}Tc-generators were manufactured by Radiopharmaceutical Laboratory-RPC, and loaded with roughly 210 mCi of fission-produced ^{99}Mo. The generators were divided into three groups, i.e. : 10 generators loaded with ^{99}Mo produced by RPC-BATAN (Radioisotope Production Laboratory), 8 generators loaded with ^{99}Mo produced by Nordion (Canada) and 10 generators loaded with ^{99}Mo from ANSTO (Australia).

Gamma spectrometric analysis was carried out using a multi channel analyzer with an HP-Ge detector (manufactured by Tennelec), a TC-244 spectroscopic amplifier (Tennelec), PS-4001 M and PS-495 power supplies (ORTEC).

Pertechnetate fraction (^{99m}Tc) was eluted from the generators by vacuum elution using saline solution as illustrated in Fig. 1. The total volume of the collected eluate was 10 mL which was similar to the total volume applied for the callibration of the multi channel analyzer used [9].

To eliminate gamma radiation from ^{99m}Tc, a lead shield with a thickness of 0.6913 cm was applied, so that only the gamma radiation with energy higher than that of ^{99m}Tc can be observed. The resulting gamma spectrum was processed by a PCA-II soft-ware to determine level of radionuclidic impurities.

RESULTS AND DISCUSSION

The simplest phenomenon showing characteristic of a chromatographic generator is radioactivity yield of the eluted radioisotope. It is defined as a comparison between the total activity eluted and the total theoretical activity, calculated at the elution time.

In this experiment, the characteristic of the ^{99m}Tc-generator was studied by evaluating the radioactivity yield of pertechnetate-^{99m}Tc. The theoretical activity was calculated from equation (i) indicating a transient equillibrium between the parent (^{99}Mo) and the daughter (^{99m}Tc) [10] :

$$A_{Tc} = A_{Mo} \cdot \frac{0.863 \times \lambda(Tc)}{\lambda(Tc) - \lambda(Mo)} \cdot \{ 1 - e^{-[\lambda(Tc) - \lambda(Mo)].\, t} \} \quad \text{..... (i)}$$

where A_{Tc} = theoretical activity of ^{99m}Tc at the time t.
A_{Mo} = activity of ^{99}Mo at the time t.
λ = decay constant (of ^{99}Mo and ^{99m}Tc respectively).
t = time of elution or separation of ^{99m}Tc, calculated from ^{99}Mo loading time.

It can be seen from Fig. 2 that the ^{99m}Tc radioactivity yields are relatively uniform between 90 – 100 % and are independent to the origin of the loaded ^{99}Mo. These phenomena indicate the constancy of the characteristic of ^{99m}Tc-generator produced by RPC. For this reason it can be assumed that the main factors influencing level of radionuclidic impurities in pertechnetate fraction are parameters of reactor operation and those of production process of ^{99}Mo bulk.

In all cases of the loaded ^{99}Mo, the consistent appearance of peaks at roughly 365 kev, 497 kev, 635 kev, 740 kev and 778 kev were clearly shown in the resulting gamma spectra of the eluted pertechnetate fraction, after eliminating radiation of ^{99m}Tc. Intensity ratio determination gave values of about 2.75 – 3.00 to 1 for the peaks at 738 – 740 kev and 776 - 778 kev, identifying them as the peaks of ^{99}Mo. The single peak appeared between 496 - 498 kev is assumed as the main peak of ^{203}Ru, whereas the peaks at 364 - 366 kev and 635 - 637 kev seem to be the peaks of ^{131}I [11].

Direct calculation by PCA-II program for the mentioned contaminants gave values of contaminant level in each of pertechnetate-^{99m}Tc fraction sample as shown in Fig. 3 (a, b and c). It was observed that in all cases the contaminants level did not exceed the maximum permissible value as defined in some pharmacopeias [8,12]. The radionuclidic impurities fluctuations, however, are different, influenced by the origin of the loaded ^{99}Mo.

Loading the generator with fission-produced ^{99}Mo from RPC- BATAN gave a wider fluctuation of radionuclidic impurities in the resulting pertechnetate fraction than loading it with fission-produced ^{99}Mo from Nordion. The use of fission-produced ^{99}Mo from ANSTO gave narowest fluctuation of radionuclidic impurities. This phenomenon is suspected to be caused by various irradiation parameters as well as production process methods, such as cyclus of irradiation, distribution and stability of neutron flux, annealing or post-irradiation decay, and radionuclide separation technique.

Fig. 3 also indicates that the level of ^{99}Mo contamination is generally higher than that of ^{131}I and ^{103}Ru contaminations. This is in conformity with the previous experiment comparing the utilization of Merck's alumina and Woelm's for ^{99m}Tc-generator [13].

As the parent of ^{99m}Tc, the ^{99}Mo potentially contaminates the resulting ^{99m}Tc because the adsorption capacity of molybdate ion on alumina resin is not very satisfied [14]. For this reason it may be important to develop ion exchanger or adsorber other than alumina in order to decrease molybdenum breakthrough from the generator system. Some inorganic synthetic compounds applied for that purpose have been reported [14,15,16].

The fission yield of ^{131}I is roughly 0.029 [11,17]. Comparing this value to that of ^{99}Mo which is roughly 0.061 [11,17], it is believable that the activity of fission-produced ^{131}I can reach up to 40 % of the ^{99}Mo's activity

[17]. In RPC, the separation of fission-produced ^{131}I is carried out by trapping it on a copper-wool column in a vaccum distillation system [18]. However, it is not very surprising to observe that ^{131}I has contaminated the fission-produced ^{99}Mo and the resulting ^{99m}Tc as well.

Other radioiodine which was occasionally observed to be radionuclidic impurities in the resulting pertechnetate was ^{132}I (the main gamma energies are about 668 kev, 773 kev and 955 kev [11]). Considering ^{132}I is a short-half-life isotope ($t_{1/2}$ = 2.28 h), there must be responsible for the existence of the ^{132}I. Radionuclide of ^{132}Te, having fission yield of 0.042 and $t_{1/2}$ of 3.26 d [11], is presumed to be responsible for the production of ^{132}I by its β decay. However, the ^{132}Te itself was not found in the resulting pertechnetate because it was not eluted off the alumina column.

Ruthenium-(^{103}Ru), having a fission yield of 0.03 and $t_{1/2}$ of 39.27 d [11], can reach the activity of up to 15 % of the ^{99}Mo's activity [17]. It is also difficult to be separated completely from ^{99}Mo [7], maybe due to some similarities of ruthenate ($RuO4^{2-}$) species compared to molybdate ($MoO4^{2-}$). On the other hand, the formation of perruthenate ($RuO4^{-}$) which resembles pertechnetate ($TcO4^{-}$) maybe responsible for the ^{103}Ru contamination in the resulting ^{99m}Tc solution. Some radionuclides of Ru other than ^{103}Ru are also formed by fission, but they are mostly short-half-life isotopes. ^{106}Ru is the only fission- produced Ru that has half life longer than that of ^{99m}Tc and ^{99}Mo [19], but it is a low-beta-emitter (E_β = 0.04 kev) having no gamma radiation.

CONCLUSION

The radioactivity yield of eluting ^{99m}Tc showed that the ^{99m}Tc-chromatographic generator produced by RPC-BATAN has a high consistency on the characteristic of the column. The yield from one generator to another was uniform in a range of 90 - 100 % and independent to the origen of the loading fission-produced ^{99}Mo.

Some radionuclides i.e. ^{99}Mo, ^{131}I and ^{103}Ru frequently contaminated the resulting pertechnetate but the contamination did not exceed maximum permissible level. The fluctuation of the contamination is suspected to be influenced by parameters of reactor operation and separation technique applied to the production of the loaded ^{99}Mo.

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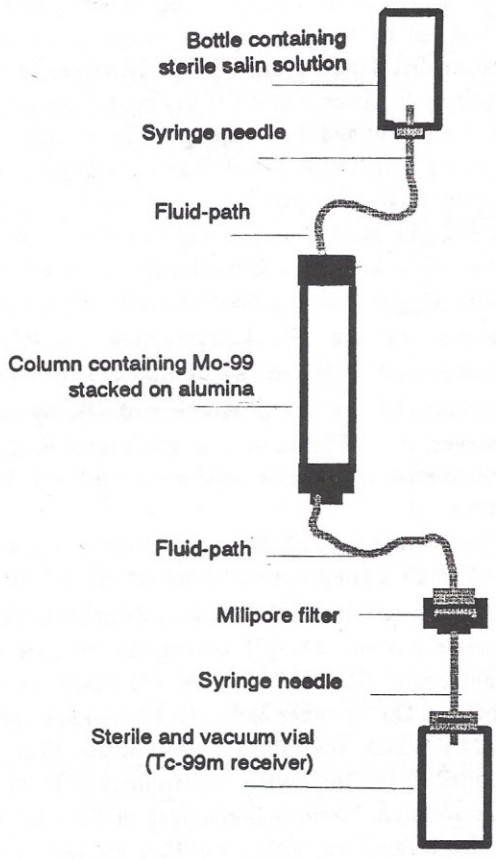


Fig. 1. Vacuum elution in the separation of ^{99m}Tc from ^{99m}Tc- Chromatographic generator.

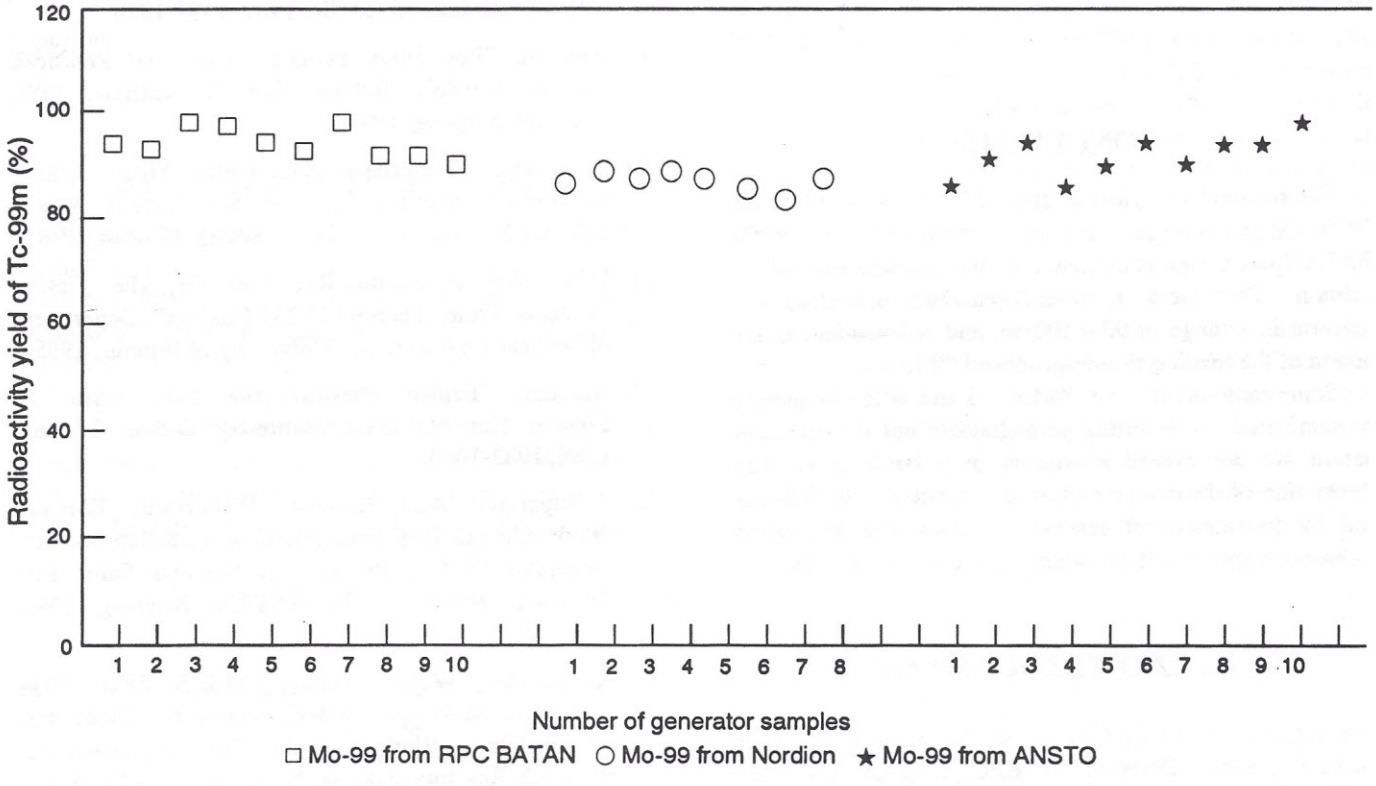
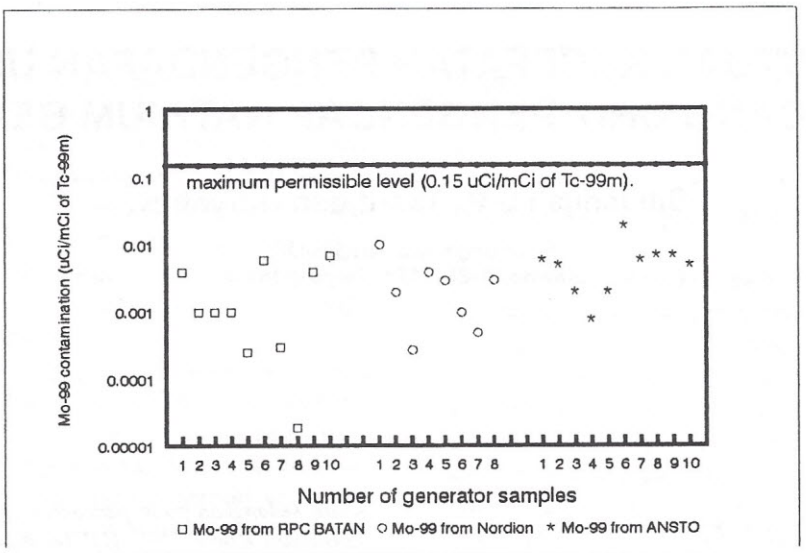
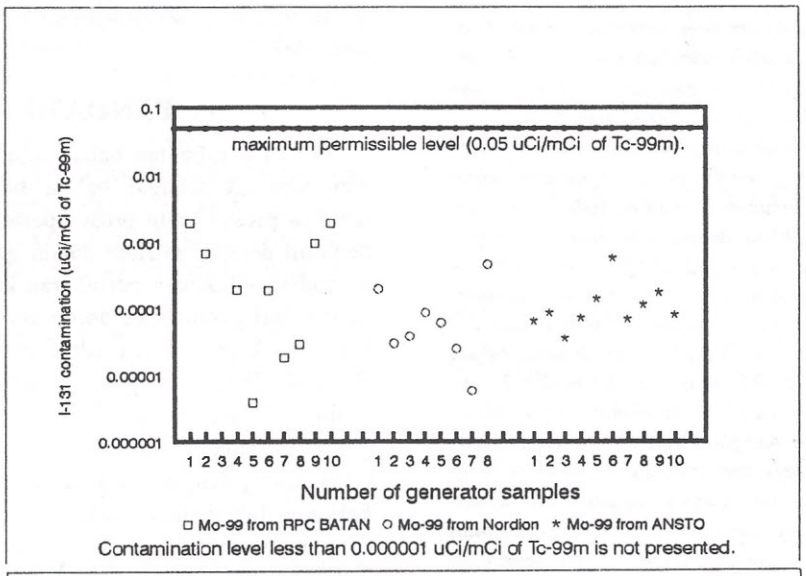


Fig. 2 ^{99m}Tc-radioactivity yield of generators loaded with various fission-produced ^{99}Mo.



(a)



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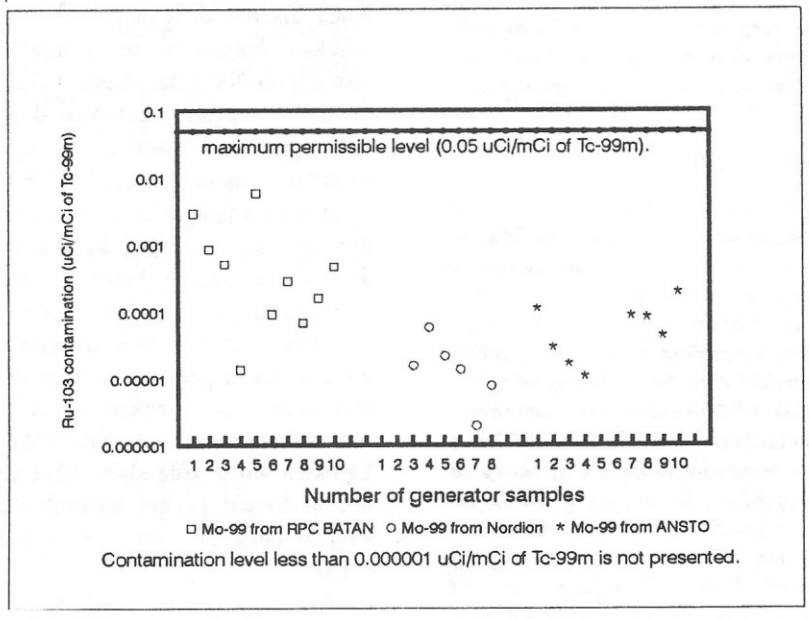

(c)

Fig. 3 Contamination level of ^{99}Mo (a), ^{131}I (b) and ^{103}Ru (c) in pertechnetate fraction eluted from generators loaded with various fission-produced ^{99}Mo.